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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 C.F.R. § 1.53(b))

Attorney Docket No. 35-0017

First Inventor or Application Identifier Keith R. Jenkin

Title See 1 in Addendum

Express Mail Label No. EK745232091US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. ☒ * Fee Transmittal Form (e.g., PTO/SB/17)
(Submit an original and a duplicate for fee processing)
2. ☒ Specification [Total Pages 45]
(preferred arrangement set forth below)
 - Descriptive title of the Invention
 - Cross References to Related Applications
 - Statement Regarding Fed sponsored R & D
 - Reference to Microfiche Appendix
 - Background of the Invention
 - Brief Summary of the Invention
 - Brief Description of the Drawings (if filed)
 - Detailed Description
 - Claim(s)
 - Abstract of the Disclosure
3. ☒ Drawing(s) (35 U.S.C. 113) [Total Sheets 5]
4. Oath or Declaration [Total Pages 3]
 - a. ☒ Newly executed (original or copy)
 - b. ☐ Copy from a prior application (37 C.F.R. § 1.63(d))
(for continuation/divisional with Box 16 completed)
 - i. ☐ DELETION OF INVENTOR(S)
Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b).

* NOTE FOR ITEMS 1 & 13 IN ORDER TO BE ENTITLED TO PAY SMALL ENTITY FEES, A SMALL ENTITY STATEMENT IS REQUIRED (37 C.F.R. § 1.27), EXCEPT IF ONE FILED IN A PRIOR APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).

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5. ☐ Microfiche Computer Program (Appendix)
6. Nucleotide and/or Amino Acid Sequence Submission
(if applicable, all necessary)
 - a. ☐ Computer Readable Copy
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ACCOMPANYING APPLICATION PARTS

7. ☒ Assignment Papers (cover sheet & document(s))
8. ☒ 37 C.F.R. § 3.73(b) Statement (when there is an assignee) ☒ Power of Attorney
9. ☐ English Translation Document (if applicable)
10. ☒ Information Disclosure Statement (IDS)/PTO-1449 ☒ Copies of IDS Citations
11. ☐ Preliminary Amendment
12. ☒ Return Receipt Postcard (MPEP 503)
(Should be specifically itemized)
13. ☐ * Small Entity Statement(s) ☐ Statement filed in prior application
(PTO/SB/09-12) ☐ Status still proper and desired
14. ☐ Certified Copy of Priority Document(s)
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☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No: _____

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SATELLITE PAYLOAD DATA COMMUNICATIONS
AND PROCESSING TECHNIQUES

BACKGROUND OF THE INVENTION

This invention relates to satellite communication systems, and more specifically relates to such systems in which satellite data is processed by an earth processing center.

Satellite communications are taking on increased importance as evidenced by the following patents issued in the name of one of the inventors of the present invention: U.S. Patent 5,867,530, entitled "Method and Apparatus for Accommodating Signal Blockage in Satellite Mobile Radio Systems," issued in the name of Keith R. Jenkin, on February 2, 1999 and U.S. Patent 5,940,444, entitled "DARS PSF With No Data Rate Increase," issued in the name of Keith R. Jenkin and Stephen J. Toner on August 17, 1999.

Prior satellite communication systems requiring earth processing centers including, for example, weather satellite

systems. In such a system, one or more traditional ground stations are used. The weather satellite collects data continuously and saves it onboard, and then "dumps" that data as it over flies a traditional ground station. Polar locations are chosen as sites for traditional polar orbiting missions since the poles are overflown on every orbit, thus minimizing the number of traditional ground stations needed. (If the stations were located elsewhere, say near the equator, a prohibitively large number of these expensive facilities and sustaining staff ringing the globe would be needed to avoid blind orbits.)

Significant Data Timeliness Compromise

Mission data is continuously collected and stored onboard until a traditional ground station is encountered. This results in data already being delayed by up to as much as approximately 100 minutes before it even reaches the ground, which for weather data is highly undesirable.

Traditional Ground Station Complexity and Cost

Since there are very few downlink opportunities, and each of them is usually critical to prevent blind orbits, the stations must have extremely reliable communications with the satellite to avoid unacceptable performance. Usually a bi-directional system is used (both downlink and

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397
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Since a downlink to a traditional ground station is a complex operation, a practical limit on the geometrically available contact time is usually imposed. The ground station antenna (which might service several other satellites too) needs to be slewed, signal acquisition accomplished, and reliable communications need to be

established. Therefore, otherwise viable contacts at a traditional ground station are discarded if the contact opportunities are somewhat short, such as five minutes (of a nominal 12 minute pass time). The preferred embodiment of the present invention does not require a minimum pass limitation, since it is a dedicated, mission-captive capability. Furthermore, even "scraps" of mission data (small periods) are useful in the preferred embodiment architecture, since it will be shown that all received valid data, no matter how small or redundant, become amalgamated or used as checks upon arrival at the processing center.

Ground Communication Drawbacks Of Prior Systems

Since the traditional ground stations are generally located in remote, sparsely populated areas, taking advantage of commercially financed, installed, and maintained fiber optic networks is unlikely since there is no financial motivation for servicing such geographic (polar) areas. This means communication from traditional ground stations to the processing center (probably in the U.S.) is expensive for the data rates (bandwidth) needed by future weather satellites. Either dedicated, sole-user fiber is needed, or perhaps a complex, risky, and expensive "hop"

from the station to a communications satellite and back to the U.S. is needed. Or, a slow existing link might be used, but because of limited bandwidth, data will again be delayed awaiting it's turn in a rate buffer queue for ground
5 communication.

Frailty Of Prior Systems

Since there are, practically speaking, several single point failure opportunities in a traditional ground station system, each point must have incredibly high (i.e.
10 expensive) reliability and sufficient availability. For instance, if a key station is down for a prolonged period, say due to earthquake damage, or immediately irreparable equipment failure, or staffing problems and so on, critical data will be lost or arrive so late it's essentially
15 useless.

Spacecraft Complexity/Risk Of Prior Systems

Since passage over a traditional ground station is on the order of 10 minutes, and the stored data is from a
20 nominal 100 minute orbit, high downlink data rates (a minimum of 10x payload data rate) need a spacecraft pointable, high gain antenna to keep spacecraft electrical power and transmitter needs reasonable. This means either

moving mechanical parts (an articulated gimbal system), or possibly a phased array antenna (complex). Since the spacecraft antenna is highly directional (continuously dynamically pointed at the ground station) and since
5 transmit power is limited, only one ground station at a time can be downlinked. Furthermore, if subsequent contact opportunities arise, a gimbaleed spacecraft antenna needs precious time to slew and repoint.

10 Station Scheduling Complexity Of Prior Systems

Since several satellites may need servicing by the same station, scheduling is complex amongst disparate systems to avoid usage conflicts. As more satellites are launched using the same stations, competition for use of the stations
15 increases and scheduling becomes increasingly complex and conflicting. Adding additional antennas, electronics, and personnel at a traditional ground station facility can help mitigate this situation, but is expensive.

The present invention addresses the foregoing
20 deficiencies of prior systems and provides a solution.

BRIEF SUMMARY OF THE INVENTION

The preferred embodiment is useful in a satellite communication system comprising at least a first satellite

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arranged to receive first data from a first source and second data from a second source displaced from the first source to receive control data and to transmit the first data and the second data to the earth. In such an environment, the first and second data may be processed by receiving the first and second data at the earth from the satellite. According to an apparatus embodiment, a first receptor terminal is arranged to receive the first data and a second receptor terminal is arranged to receive the second data. The first and second data are transmitted to a location adjacent the earth for processing. In the apparatus embodiment, the transmitting is achieved by a wide band network. The first data and second data are processed at the earth. In the apparatus embodiment, the processing is achieved by a processing center. By using the foregoing techniques, the first and second data may be processed with increased speed and at reduced cost.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic representation of a preferred form of communication system employing communication satellites and embodying the invention.

Figure 2 is an enlarged view of one of the satellites shown in Figure 1.

Figure 3 is a schematic block diagram of a preferred form of receptor terminal made in accordance with the invention.

Figure 4 is a schematic block diagram illustrating a preferred form of data recovery in the event of an anomaly in the system shown in Figure 1.

Figure 5 is a schematic block diagram of a portion of a preferred form of processing center employing a plurality of computers.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Glossary of Terms Used in this Specification

"Autonomous Mode" An alternative embodiment where the system is completely autonomous, yet with coverage immunity to failures. Improvements and repairs still can be made on the ground only.

"Traditional Ground Stations" In the context of this specification, this refers to large, complex, expensive, facilities used for many years in the past to support communications with various satellite systems.

"Receptor" The preferred embodiment may use, for example, a distributed network of small extremely simple, and relatively inexpensive, unmanned antenna/receivers that

5 noted above.

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"Virtual Spherical Coverage" A feature whereby the whole earth can be mapped in a timely and confident (high data

1. Demographic Data		2. Clinical Data		3. Laboratory Data		4. Treatment Data		5. Outcome Data	
Variable	Value	Variable	Value	Variable	Value	Variable	Value	Variable	Value
Age (years)	65.2	Sex (Male/Female)	45/20	Weight (kg)	78.5	Height (cm)	175.3	BMI (kg/m²)	25.8
Weight (kg)	78.5	Height (cm)	175.3	BMI (kg/m²)	25.8	SBP (mmHg)	145.2	DBP (mmHg)	95.1
SBP (mmHg)	145.2	DBP (mmHg)	95.1	HR (b/min)	72.5	ECG (Normal/Abnormal)	15/10	X-ray (Normal/Abnormal)	12/8
ECG (Normal/Abnormal)	15/10	X-ray (Normal/Abnormal)	12/8	Lab Test 1 (Normal/Abnormal)	18/12	Lab Test 2 (Normal/Abnormal)	14/16	Lab Test 3 (Normal/Abnormal)	10/20
Lab Test 1 (Normal/Abnormal)	18/12	Lab Test 2 (Normal/Abnormal)	14/16	Lab Test 3 (Normal/Abnormal)	10/20	Treatment 1 (Yes/No)	25/15	Treatment 2 (Yes/No)	20/20
Treatment 1 (Yes/No)	25/15	Treatment 2 (Yes/No)	20/20	Outcome 1 (Success/Failure)	30/10	Outcome 2 (Success/Failure)	25/15	Outcome 3 (Success/Failure)	20/20
Outcome 1 (Success/Failure)	30/10	Outcome 2 (Success/Failure)	25/15	Outcome 3 (Success/Failure)	20/20				

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preoccupied servicing another satellite having higher communication priority, 2) a ground station is down (inoperable) due to scheduled maintenance or unscheduled failure of it's own equipment or it's communication to the final data delivery point (e.g. ground communication to the U.S.), 3) ground station staff insufficient, 4) severe weather at a ground station (e.g. extreme wind requiring antennas to be caged), 5) RF interference avoidance with another component.

"Blind Orbit" An orbit where a satellite has had no opportunity to pass (downlink) Mission Data because of either a geometrically impossible situation (no ground stations within communication range on that orbit), or all communication opportunities were preempted. This is a very undesirable situation for missions where data timeliness is important, since onboard stored mission data will include an additional whole orbit's worth of delay by the time it is finally downloaded.

"LEO, MEO, and GEO" Grouping general classes of Earth orbiting satellites by their gross altitude.

LEO: Low Earth Orbit (in the hundreds of kilometers altitude range).

GEO: Geosynchronous Earth Orbit (an altitude of around 36,000 kilometers, if circular, resulting in the satellite having an orbital period the same as Earth's rotation (one day), causing it to appear stationary overhead to an observer at a fixed location on Earth.)

"Sun-Synchronous-Polar-Orbit" At certain circular orbit altitudes and associated inclinations (e.g. around 800 Km and a few degrees of inclination) a satellite's orbit plane follows the Sun-Earth annual cyclic vector angular motion in inertial space. Such an orbit is advantageous to missions, such as the weather satellite mission. This orbit results in the entire Earth being mapped in a relatively short time at desirable constant sun illumination angles, owing to the combined dynamic geometry of the Earth's daily rotation, plus orbital motion, plus the cross-track swath of the satellite sensor's field-of-view. For global weather observation from relatively low altitudes (e.g. LEO versus GEO), this is an ideal scenario: full spherical coverage from consistent observation angles updated fairly frequently.

"SSR" Solid State Recorder. Recently satellites have been implementing onboard data storage with solid state recorders, in lieu of earlier data storage implementations such as mechanical tape recorders. SSRs are essentially

5 large amounts of RAM (as in a computer) plus some controlling circuitry. Obviously the elimination of moving parts (which eventually wear out and are prone to failure) is a reliability advantage. More importantly for system 10 is the random addressing capability (the "R" in RAM), programmability, and asynchronous operation, as will be shown.

"Code and Coding" Two disparate uses: 1) Code referring to computer program instructions, and 2) Coding referring to data overhead for error detection/correction algorithms.

15 "Satellite Operations Center" Usually a single facility for controlling satellites. Here commands are sent to the satellite to specify it's operation.

"Processing Center" Where mission data arrives to be converted to useful information for the intended end use.

20 For instance, in connection with the preferred embodiment, weather maps are produced by analyzing (via computer) multi-spectral imagery data collected by the satellite with

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algorithms that can convert that raw data to a useful end product format.

The preferred embodiment is useful for many possible satellite/system configurations of varying characteristics and missions. However, the preferred will be described for purposes of illustration, but not of limitation, in connection with an LEO circular Sun-Synchronous-Polar-Orbit weather mapping satellite system. For this example, timely global mapping is important to mission objectives. (Weather data is highly perishable, since weather conditions are highly dynamic.) Such a weather satellite system may have several sensors (data collection instruments), spanning a large range of the electromagnetic spectrum in observation of weather-related phenomenology below the satellite. Such sensors typically produce a steady stream of mission data, typically of high density (high data rates, such as that needed for multi-spectral imaging).

Referring to Figure 1, the preferred embodiment includes a satellite communication system 10 comprising a weather satellite 20 circling the earth E in an LEO 21. Another identical weather satellite 22 circles the earth E in another LEO (not shown). System 10 also includes a processing center PC and receptor terminals A, B and C which

are linked to center PC by a wide band optical fiber network 30, including links 32, 34 and 36.

The satellites 20 and 22 of the preferred embodiment have an orbital period of about 100 minutes (about an hour and a half per orbit), and have a Mission Data rate of about 20 Mbps, a continuous stream of the amalgam of all sensor data (megabits per second). The data stream may consist of raw data, or compressed data of either the lossy or non-lossy variety. The data stream also includes any overhead information as noted, including data encryption details. For simplicity, this example assumes that the Mission Data is always at a fixed, constant rate coming from the mission sensors, which is adequate for illustration. An actual system may have a variable rate in practice, for efficiency (compression), or scene-content variation (e.g. some sensors may not function at nighttime) or other reasons.

Global Fiber Optics Ground Communication Network 30

A wide band network, such as network 30, is known to those skilled in communications. There are many references in the open literature describing the present and future status of wide band networks, such as fiber optic cables. All of the significantly populated continents are encircled in fiber optics cable, such as cables 32, 34 and 36 that can

pass a minimum of 40 Gigabits per second. In the next couple of years, the entire globe (with the exception of arctic Polar Regions having nil population and commerce) will be a "spider web" of multi-terabit fiber optic cable. This is due to fiber optics technology where many optical spectral bands are used in a single fiber strand to produce nearly a two order of magnitude increase in communication data rates. The preferred embodiment uses this extremely fast and inexpensive communication from it's receptors, such as A, B and C, located most anywhere on earth, back to the Processing Center, PC. The bandwidth proportion needed by a weather satellite system, such as the one shown in Figure 1, is on the order of one-one-hundred-thousandth of the capability of a terabit optical fiber, which is essentially epsilon and therefore very inexpensive. The preferred embodiments also may be used for applications other than a weather satellite system, such as television, HDTV, Internet, telephone (including video soon), videoconferencing, and financial data communications. Thus, the preferred embodiments take advantage of this global inexpensive communications capability financed by commercial/consumer markets, instead of the traditional

method of utilizing mission-dedicated ground communication means.

SSR Programmability and Flexibility

Referring to Figure 2, satellite 20 includes an on-board processor 23, which stores mission data in an SSR 24 that may take the form of a recirculating memory. In the past, satellite data storage methods such as mechanical tape recorders would operate in a mode of continuous recording while out of ground station contact, then high rate playback during a downlink pass, in a fairly rigid sequential modality. SSR 24, on the other hand, can be treated like RAM in computer 23: access to all memory data at any time and in any order is possible, both for recording (writing), and non-destructive and highly selective playback (reads). The preferred embodiment uses these SSR features of random access and non-destructive reading in several ways.

The preferred embodiment uses globally distributed simple and inexpensive "receptors" A, B and C. These preferably are small, unmanned antenna installations located at easy access points to the global fiber optic network.

Referring to Figure 3, exemplary receptor terminal A includes a small dish antenna 40 approximately two to four meters in diameter, an antenna pointing gimbal control unit

44 (e.g. servos and encoders), an appropriate antenna feed
48, a receiver/demodulator 50 which downconverts the carrier
signal received from one of satellites 20 or 22, and
interfacing electronics 60 to the commercial fiber optics
5 network link 34. A phased array antenna could also be used.

Receptor terminal A receives the open-loop broadcast
signal from an over flying satellite, collects the RF signal
the satellite is transmitting, demodulates the signal to a
digital format, adds simple periodic "wrap" tagging headers
10 of time and location and synchronization bit patterns around
an arbitrarily sized "macro packet," and forwards the raw
bit stream via commercial optical fiber link 34 to the
processing center PC. There are no complex data operations
at the receptor, it merely acts as a bridge from the
15 satellite broadcasts to the processing center. No data
analysis or assessment or decisions are made, nor are any
processing operations done by the receptors. They simply
collect data and pass it along. Since the receptors are very
simple and small and located on existing fiber
20 communications channels, their deployment and operation is
very cost effective.

It will be shown that a modest number of receptors is
needed to implement the preferred embodiment because the

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preferred embodiment employs virtual spherical coverage which mitigates the fact that several gaps exist in true geometric coverage opportunities. In the preferred embodiment, 12 receptors are used to achieve reasonable
5 coverage. Depending on the needs of the system, at least twice that many receptors may be deployed.

Still referring to Figure 3, receptor terminal A also includes a GPS antenna 70 and a GPS receiver 72 which can, for example, receive the time of day. A computer with
10 ephemeris tracking software 80 controls gimbal control unit 44 in a well known manner. A mass data storage unit 90 stores mission data in case of problems.

Referring to Figure 4, system 10 includes a satellite or mission operations center 100 comprising an adaptive
15 logic controller 102 which automatically and transparently adapts system 10 to any dynamic operational scenario without compromising data quality or incurring data loss. Controller 102 provides receptor failure mitigation, and automatic system acclimation/adoption of new receptors added
20 to the system. In a sense, the system 10 "learns" as it operates, and continuously, and independently adapts to system configuration changes. In other words, system 10 provides a practical virtual spherical coverage system with

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data integrity and minimal, if any, data loss. System 10 also provides near real time data collection to data delivery time, a robust and forgiving mode of operation, a life cycle cost advantage, easy growth and expandability.

5 System 10 also provides nearly continuous downlink coverage for LEO and MEO satellites.

Referring again to Figures 1 and 2, satellites 20 and 22 comprise conventional LEO satellites consisting of the usual, normal subsystems for providing power, attitude control, orbit maintenance, a benign thermal environment, and command/status communication, etc. The satellites also include sensors 27 and 28 for gathering weather data.

The satellite mission data collection subsystem for satellite 20 comprises medium data rate (say 4x sensor data rate) data downlink equipment 25 including programmable SSR 24 (random access), conventional data multiplexing, coding, and encryption functions, and a fixed, wide field of coverage broadcast antenna.

The function of this medium data rate satellite downlink communicating subsystem is to transmit mission data continuously, and to store it for short periods during communication gaps and transmit it along with real time mission data at the next receptor encounter. This

broadcasting on cue is metered by periodically updated, preloaded commands and a frequently updated onboard stored digital contact zone reference map.

Referring still to Figure 1, system 10 includes simple
5 low cost, modest reliability, unmanned receive-only
terminals A-C located at generally equally globally
distributed convenient sites. The receptors are in
reasonable proximity to the worldwide network of fiber optic
communication channels 32, 34 and 36 for fast and cheap
10 passage of received mission data to a common mission
Processing Center PC. The receptors can, for example, be
mounted on the rooftops of existing facilities, including
government embassies (U.S. and or friendly countries),
commercial global communications provider's facilities (e.g.
15 MCI or AT&T), military installations, suitable traditional
ground station sites, or any of several global satellite
command and control facilities. Anywhere cheap fiber optics
communication is available. Note that if a location
critically needs a receptor for ultimate mission data
20 timeliness in that locale but fiber communication isn't
within practical reach, a "bounce" to a convenient comsat
could be set up with existing available equipment, or
perhaps a microwave or coaxial cable, or a conventional

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communications link (e.g. T1) to the closest fiber optic network interface. A receptor could be installed on military or commercial ships having adequate communication links, with five-space motion backed out of pointing commands.

Still referring to Figure 1, system 10 includes a traditional satellite operation center 100 for sending operating commands to satellites 20 and 22. In system 10, center 100 is identical to a traditional command center and operation, except that SSR and medium data rate transmission commands and onboard maps are included in the command stream, which are prepared from system health information gleaned from mission data reception at the processing center PC.

Referring to Figure 1, the PC provides a facility where all mission data from the satellite(s) arrives to be analyzed and formatted for end use by specialized science-based algorithms, a common function of weather systems. At the PC, data integrity is continuously tested ("checksums" and/or one-on-one redundant data duplicates compared from circuitous routes) and any necessary system reconfiguration commands forwarded to the satellite 20 and 22. Note that these are very low data rate and occasional commands that

center PC and operations center 100 may reside in one and the same physical (shared) facility, in a convenient location such as a city in the continental U.S.

Referring to Figure 1, Mission Data collection is achieved in a conventional manner by satellites 20 and 22.

10 Sensors 27 and 28 continuously observe the Earth and it's
atmosphere producing a continuous stream of data. Onboard
electronics then condition the data, multiplexing various
data sources, compressing, encrypting, and other common data
formatting operations. (As noted above, the data rate for
15 convenient illustration here is assumed at a constant rate,
but could also be variable.)

In satellite 20, data is routed to two destinations: the first to the SSR 24 (Figure 2) for continuous onboard storage, and the second to a multiplexer at the medium data rate broadcast downlink transmitter. At the multiplexer it is always continually broadcast in real time as data is collected. At the SSR destination it is also always continuously stored incrementally in time (sequence).

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So, system 10 asserts that it's anticipated transmissions to expected active contacts will be successfully received by receptors, such as A-C, and

forwards the transmissions to processing center PC, open loop, according to it's onboard contact availability map. When a gap in coverage is indicated by the map, that data (being continuously stored in the ring buffer 24) is marked for later transmittal, is retrieved from the SSR 24 and is multiplexed along with the continuously transmitted real time data. The system 10 is anticipatory: it downlinks saved gap data when the satellite is confident it will successfully be received. (If that fails, the data will still be retrieved at the next opportunity once the missing data is reported.)

Referring to Figure 4, if for some reason a segment of that open loop data never makes it successfully to the processing center PC when anticipated, it can be requested for retransmission (automatically) by the SOC 100 logic. Such a request would occur, for example, if a receptor was physically damaged in a storm, or lost it's source of electrical power. The coverage map is then updated for future use with that receptor removed and uplinked at the next opportunity to the satellite to correct it's future contact profile assertions. (The center 100 has the same coverage map and knows when data should arrive.) Note that even though the system 10 is nominally a very simple open

loop arrangement, it can retrieve missing or noisy data segments well within a reasonable delay time.

A traditional system, always has forced substantial delay since contact opportunities are widely spaced. If a traditional expected ground station contact is missed, serious excess latency results, rendering the data essentially useless for dynamic weather use. Thus, a traditional system critically needs and relies on every one of it's infrequent downlink opportunities, whereas the system 10 recovers quickly and is immune to data tardiness if a receptor pass is missed.

Another embodiment ("Autonomous") is possible. For some applications, the alternative may be a potential additional but possibly acceptable burden on downlink channel use. It is akin to the patents referenced in the background section. The satellite would continuously broadcast time-shifted data copies from earlier periods in it's orbit, in a post facto fashion. For example, if, say, four layers of time shifted data were continually broadcast assertively (open loop) to receptors having typically a ten minute pass, about a quarter of an orbit's prior data could be received automatically by a single receptor in that vicinity. As is described in the reference patents, a

similar technique for increased downlink and ground communications would be to reduce the quality (lossy compression) or to partially select critical data sections, and thus reduce the data rate of the redundantly transmitted layers. Data would still get to the destination in a timely and complete manner, but with a slightly reduced fidelity. This totally open loop, virtual spherical coverage mode could be a backup, fail safe modality. If the satellite is for any of several reasons not receiving a normal uplink command profile, the satellite could automatically default and reconfigure to this totally autonomous mode. This would still provide full Earth coverage, even if receptors randomly fail. In other words, the system is completely automated, and any repairs need for continuous coverage are made on the ground (repair inoperable receptors or supplement them with nearby additional receptors,).

In the case of noisy data receipt, for perhaps a temporary reason such as a severe local storm at a receptor (e.g. "rain fade"), then the coverage map will still get updated as a precaution for further use, and that noisy data gets subsequently recovered, since the system also gracefully and automatically recovers from both a temporary

compromise in a receptor's performance, as well as from prolonged permanent outages. Note that noisy data (beyond correction capabilities) can be short term ("bursty") in system 10, and the whole pass over a receptor is mostly
5 valid and saved, and only the noisy parts recouped as needed.

System 10 automatically recognizes and adjusts the coverage map when a new receptor is brought on line. There is no need to tell the system it has been added and to look
10 for it. Also note that receptor deployment and installation is remarkably easy: a contracted local technician simply unpacks the unit (in maybe two or three convenient pieces), secures the receptor stanchion in approximately the appropriate North/South orientation (via a magnetic compass
15 or handheld GPS unit), and squares it vertically with a bubble level. Once power is provided and network communication (fiber optics connection) is established by conventional commercial methods, installation is complete. This crude initial orientation is adequate, since the
20 receptor is initially commanded in a simple search pattern remotely from the operations center, pointing the receptor antenna generally in the direction at the right time when a known system 10 satellite will over fly. Since the system 10

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satellites are continuously transmitting real time data, no coordination or cooperation is necessary. The processing center PC will suddenly start receiving valid data from the new receptor and adjust the common coverage map accordingly.

- 5 Any receptor misalignment is dialed in as a bias to it's future pointing commands from the operations center. Since the satellite (instant) location is very accurately known from it's orbital elements, and the location of a receptor is also accurately known and fixed (via a onetime GPS
10 handheld measurement), the precise pointing locii for all satellite/receptor dynamic combinations is easily and accurately calculated. There is no need for constant "hunting" and handshaking for acquisition. The receptor is simply told where and when to point, and passes along
15 whatever it receives.

At least three means of insuring data integrity (successful and complete data receipt) are available and implemented in system 10:

- Traditional error detection/correction overhead bits
20 embedded in the data stream right on the satellite. (The usual digital communications procedure).

By comparing a delayed (time-shifted) "checksum" (etc.) stream of each original data packet (embedded in the

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Duplicate receipt of identical packets can occur if the contact patterns of two or more receptors overlap, which is a likely situation. Thus, the processing center PC can receive duplicate data from circuitous routes and physical locations. These can be compared one-bit-for-one-bit exactly after error correction and normal goodness tests have been passed, and if there is a difference, something is suspect. (The system 10 can always tell multiple receptors overlapping in coverage to selectively not transmit those zones to save fiber communications costs and overly redundant data retrieval.)

System 10 also provides for satellite command intrusion immunity. A valid concern is the potential of a renegade individual or group sending unauthorized commands to a spacecraft for whatever reason. As such, traditional ground stations are highly secured to alleviate the possibility of

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(temperature, wind conditions, humidity and others), or more complex such as automatic cloud cover assessment devices. A simple video camera and microphone at the receptor could also be handy for remote receptor health assessment.

5 A significant cost savings and simplification of the processing center ("PC") occurs when system 10 is used instead of a traditional ground station architecture. In a traditional system, data arrives at the processing center in bursts, as spacecraft in the constellation rapidly downlink
10 to a station data collected during one orbit of the spacecraft around the earth. There are long quiet periods at the PC when the spacecraft are away from station coverage for prolonged stretches. Since these PC abrupt ingest bursts can be from any one of the spacecraft in a
15 constellation, an obvious approach is to share the PC computing capacity among the various spacecraft for computing resource efficiency. However, there is substantial complexity and development cost associated with managing one large computer resource to service several
20 different spacecraft simultaneously and asynchronously. In System 10, however, data arrives at the PC from all spacecraft more or less continuously, with the exception of brief receptor coverage gap zones. This makes practical a

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20, whereas processor 112 is dedicated to processing mission data received from satellite 22. The data from the satellites is switched to the proper processor by a controller 108. By using this technique, processors may be lower capacity and lower cost than providing a single high speed processor to process data for both satellite 20 and satellite 22. In addition, each processor may be programmed to handle any algorithms which are unique to the type of data being processed from a particular satellite.

When a new satellite comes on line, a new processor is added and may be programmed to handle the data from the new satellite. Since satellite systems advance rapidly in capability, this technique ensures that the processing center will not become obsolete when a new satellite begins to feed data to the processing center. The existing satellites and their respective computers may continue to function. The new satellite can be brought on line by merely programming a new computer to handle its needs while the existing computers continue to function as in the past.

In summary, the preferred embodiment offers at least the following advantages over the known traditional systems:

- 1) Near-zero final weather product timeliness: continuous data from all satellites instead of bursts of large amounts of widely separated (in time) data bunches;
- 2) Robustness;
- 3) Growth and redundancy;
- 4) No orbital phasing control required; any initial phasing, any orbit drift is accommodated
- 5) Downlink bandwidth can be in the tens of Mbps;
- 6) "Preemption" concerns disappear; planned, random, pronounced, or permanent;
- 7) Unmanned (no human errors, training, housing, management);
- 8) Security issues and concerns eliminated or more easily controlled;
- 9) Life-Cycle-Cost reduction; more economical overall (inexpensive terminals, no staffing);
- 10) Spacecraft simplified, more reliable (no gimbaled antenna: fixed/shaped beam);
- 11) Can be an independent adjunct to "Traditional" ground stations (enhancement, backup);
- 12) No need to artificially crop physical contact opportunities (no minimum pass time imposed);

13) No S/C-to-Ground Station coordination, cooperation,
scheduling (mostly gone);

14) Mix and match orbits (e.g. different missions,
different altitudes/periods) (no competition for station
5 time);

15) Potential external funding since the system could be
utilized by other future satellite systems;

16) No concern about simultaneous downloads to same
terminal (physically can't);

10 17) Simple deployment and installation ;

18) An excellent approach to system autonomy (Autonomous
Mode) .

Those skilled in the art will recognize that only the
preferred embodiments of the invention have been described
15 in this specification. These embodiments may be modified
and altered without departing from the true spirit and scope
of the invention as defined in the accompanying claims.

What is claimed is:

1 1. In a satellite communication system comprising at
2 least a first satellite arranged to receive first data from
3 a first source and second data from a second source
4 displaced from the first source, to receive control data and
5 to transmit the first data and the second data, apparatus
6 for processing the first and second data comprising in
7 combination:

8 an earth processing center arranged to process the
9 first data and second data;

10 a wide band network arranged to transmit the first and
11 second data to the processing center;

12 a first receptor terminal arranged to receive the first
13 data from the satellite and to place the first data on the
14 network for transmission to the processing center; and

15 a second receptor terminal arranged to receive at least
16 the second data from the satellite and to place at least the
17 second data on the network for transmission to the
18 processing center.

1 2. Apparatus, as claimed in claim 1, wherein the
2 satellite comprises a memory for storing the first and
3 second data.

[illegible][illegible][illegible]

1 6. Apparatus, as claimed in claim 1, wherein the
2 satellite transmits the first data and second data to the
3 second receptor in the event the first receptor terminal is
4 unprepared to receive the first data and the second receptor
5 terminal is prepared to receive the first data and second
6 data.

1 7. Apparatus, as claimed in claim 1, wherein the
2 second receptor terminal is arranged to receive the first
3 data and to place the first data on the network for
4 transmission to the processing center in the event the first
5 data is not received by the first receptor terminal.

1 8. Apparatus, as claimed in claim 1, wherein the
2 satellite comprises a sensor arranged to receive the first
3 data and second data.

1 9. Apparatus, as claimed in claim 1, wherein the
2 system comprises a satellite operation center connected to
3 the first receptor terminal and second receptor terminal by
4 the network, the satellite being arranged to transmit the
5 control data to the satellite.

1 10. Apparatus, as claimed in claim 9, wherein the
2 operation center is arranged to signal the satellite to
3 transmit the first data to the first receptor terminal in
4 the event that the processing center detects a deficiency in
5 the first data.

1 11. Apparatus, as claimed in claim 9, wherein the
2 operation center is arranged to signal the satellite to
3 transmit the first data to the second receptor terminal in
4 the event that the processing center detects a deficiency in

5 the first data and the satellite is out of range of the
6 first receptor terminal.

1 12. Apparatus, as claimed in claim 1, wherein the
2 system comprises a second satellite arranged to receive
3 third data from a third source and fourth data from a fourth
4 source displaced from the third source, to receive control
5 data and to transmit the third data and the fourth data,
6 wherein the system comprises at least a third receptor
7 terminal arranged to receive the third and fourth data and
8 to place the third and fourth data on the network for
9 transmission to the processing center and wherein the
10 processing center comprises a first computer arranged to
11 process the first and second data and a second computer
12 arranged to process the third and fourth data.

1 13. Apparatus, as claimed in claim 1, wherein the
2 network comprises an optical network.

1 14. In a satellite communication system comprising at
2 least a first satellite arranged to receive first data from
3 a first source and second data from a second source
4 displaced from the first source, to receive control data and
5 to transmit the first data and the second data to the earth,
6 a method of processing the first and second data comprising
7 in combination:

8 receiving the first data at the earth from the
9 satellite;
10 transmitting the first data adjacent the earth for
11 processing;
12 receiving at least the second data at the earth from
13 the satellite;
14 transmitting at least the second data adjacent the
15 earth for processing; and
16 processing the first data and second data adjacent the
17 earth.

1 15. A method, as claimed in claim 14, and further
2 comprising storing the first and second data on the
3 satellite.

1 16. A method, as claimed in claim 14, and further
2 comprising receiving the first data at the satellite at a
3 first time and receiving the second data at the satellite at
4 a second time later than the first time.

1 17. A method, as claimed in claim 16, and further
2 comprising transmitting the first data from the satellite at
3 a third time occurring after the first time and transmitting
4 the second data from the satellite at a fourth time
5 occurring after the second time.

1 18. A method, as claimed in claim 14, and further
2 comprising transmitting the first data from the satellite to
3 a first location on the earth in the event the first
4 location is prepared to receive the first data and
5 transmitting the second data from the satellite to a second
6 location on the earth in the event the second location is
7 prepared to receive the second data.

1 19. A method, as claimed in claim 14, and further
2 comprising transmitting the first data and second data to a
3 second location on the earth in the event that a first
4 location on the earth is unprepared to receive the first
5 data and the second location is prepared to receive the
6 first data and second data.

1 20. A method, as claimed in claim 14, and further
2 comprising signaling the satellite to transmit the first
3 data to a first location on the earth in the event that the
4 processing detects a deficiency in the first data.

1 21. A method, as claimed in claim 20, and further
2 comprising signaling the satellite to transmit the first
3 data to a second location on the earth in the event that the
4 processing detects a deficiency in the first data and the
5 satellite is out of range of the first location.

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1 22. A method, as claimed in claim 14, wherein the
2 system comprises a second satellite arranged to receive
3 third data from a third source and fourth data from a fourth
4 source displaced from the third source, to receive control
5 data and to transmit the third data and the fourth data to
6 the earth, and wherein the method further comprises
7 receiving the third and fourth data, wide band transmitting
8 the third and fourth data for processing, processing the
9 first and second data with a first operating system and
10 processing the third and fourth data with a second operating
11 system.

1 23. A method, as claimed in claim 14, wherein the
2 transmitting comprises wide band transmitting.

1 24. A method, as claimed in claim 14, wherein the
2 transmitting comprises optical transmitting.

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SATELLITE PAYLOAD DATA COMMUNICATIONS
AND PROCESSING TECHNIQUES

ABSTRACT OF THE DISCLOSURE

A satellite communication system (10) includes a satellite (20) which receives first and second data from sources. Each satellite receives control data from a satellite control center (100). An earth processing center (PC) is arranged to process the data received from the satellites, and a wide band network (30) is arranged to transmit the data to the processing center. A receptor terminal (A) is arranged to receive the first data and to place the first data on the network (30) for transmission to the processing center (PC). A second receptor terminal (B) is arranged to receive the second data and to place the second data on the network (30) for transmission to the processing center (PC).

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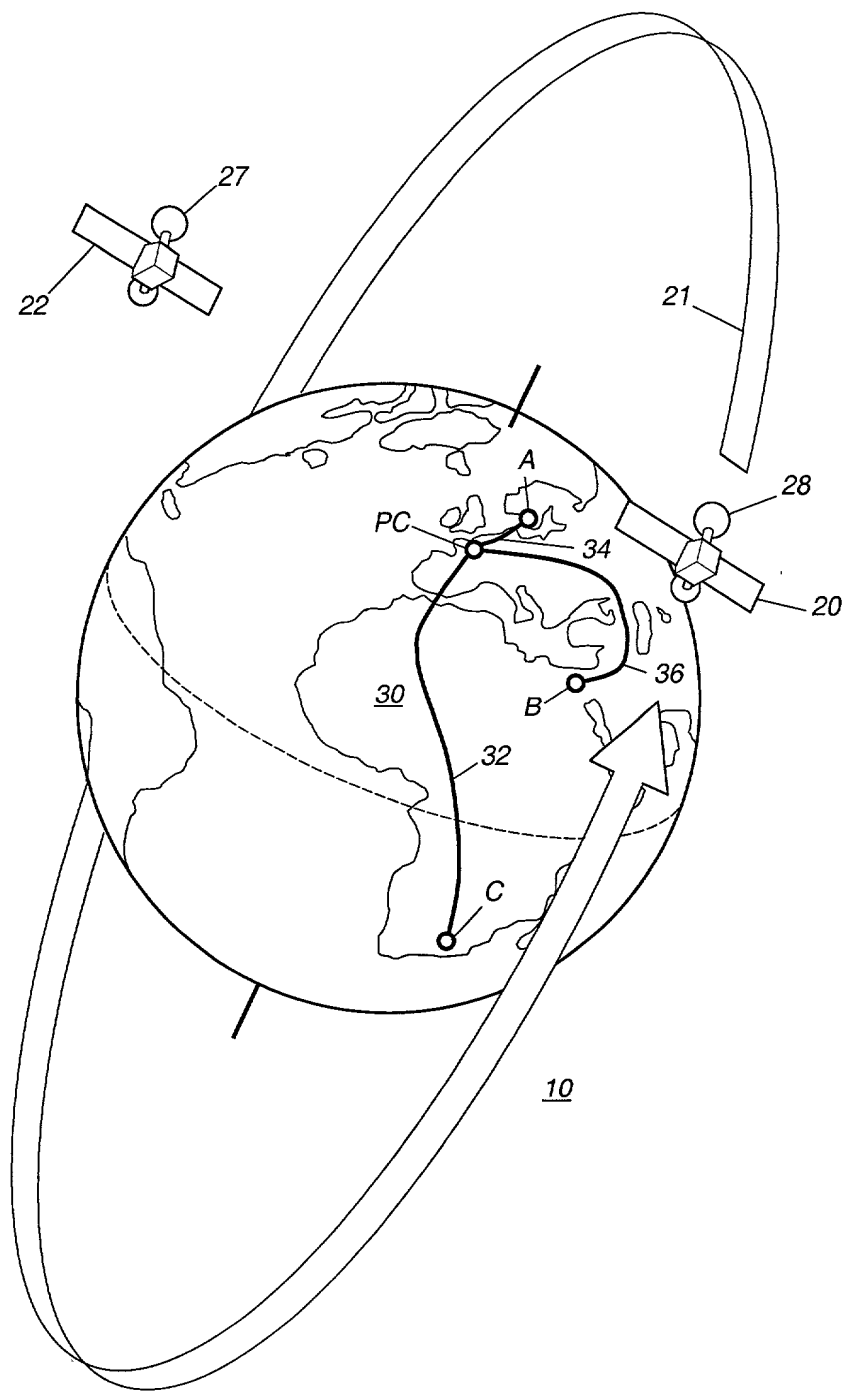


Fig. 1

Fig. 2

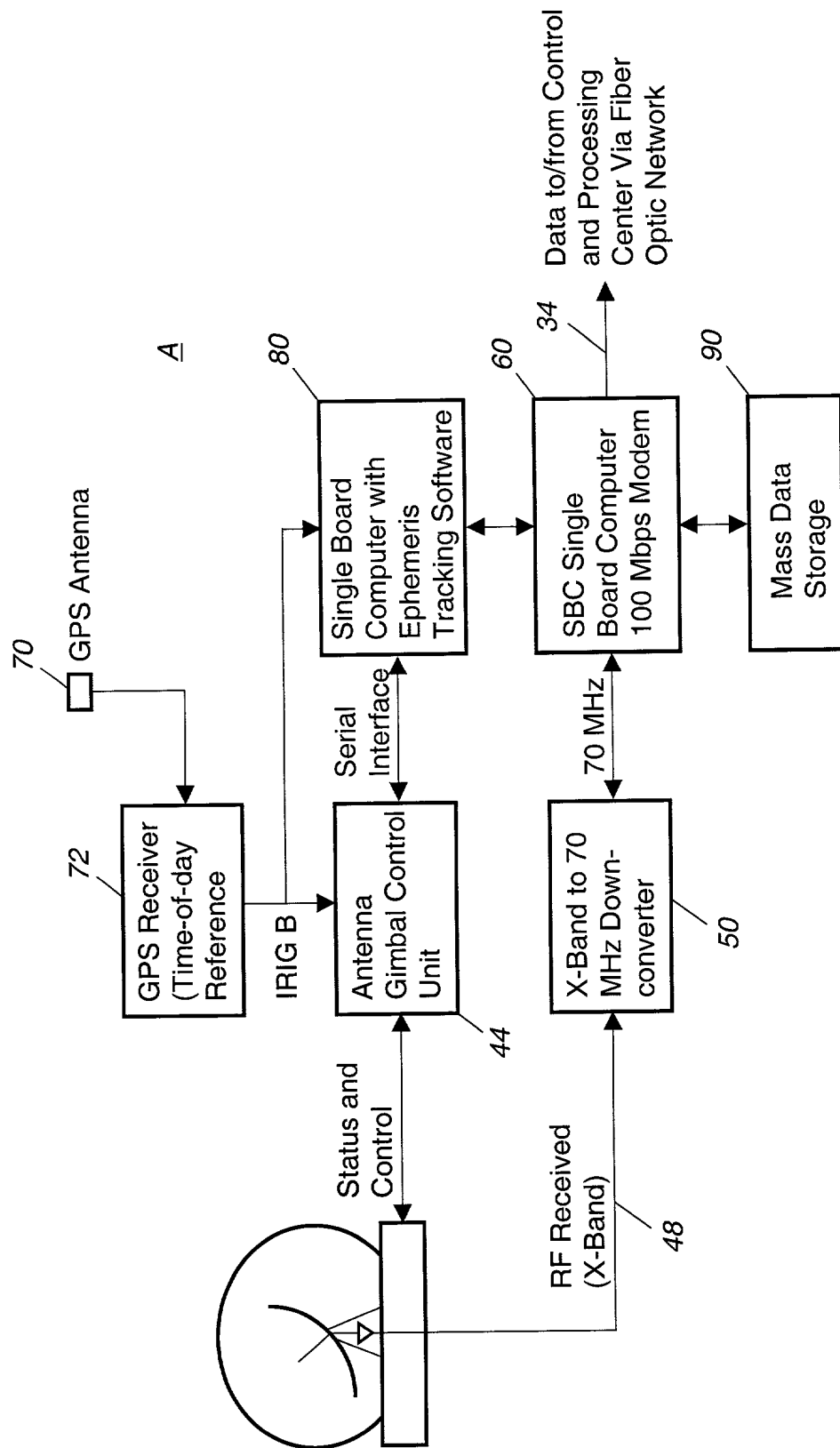


FIG. 3

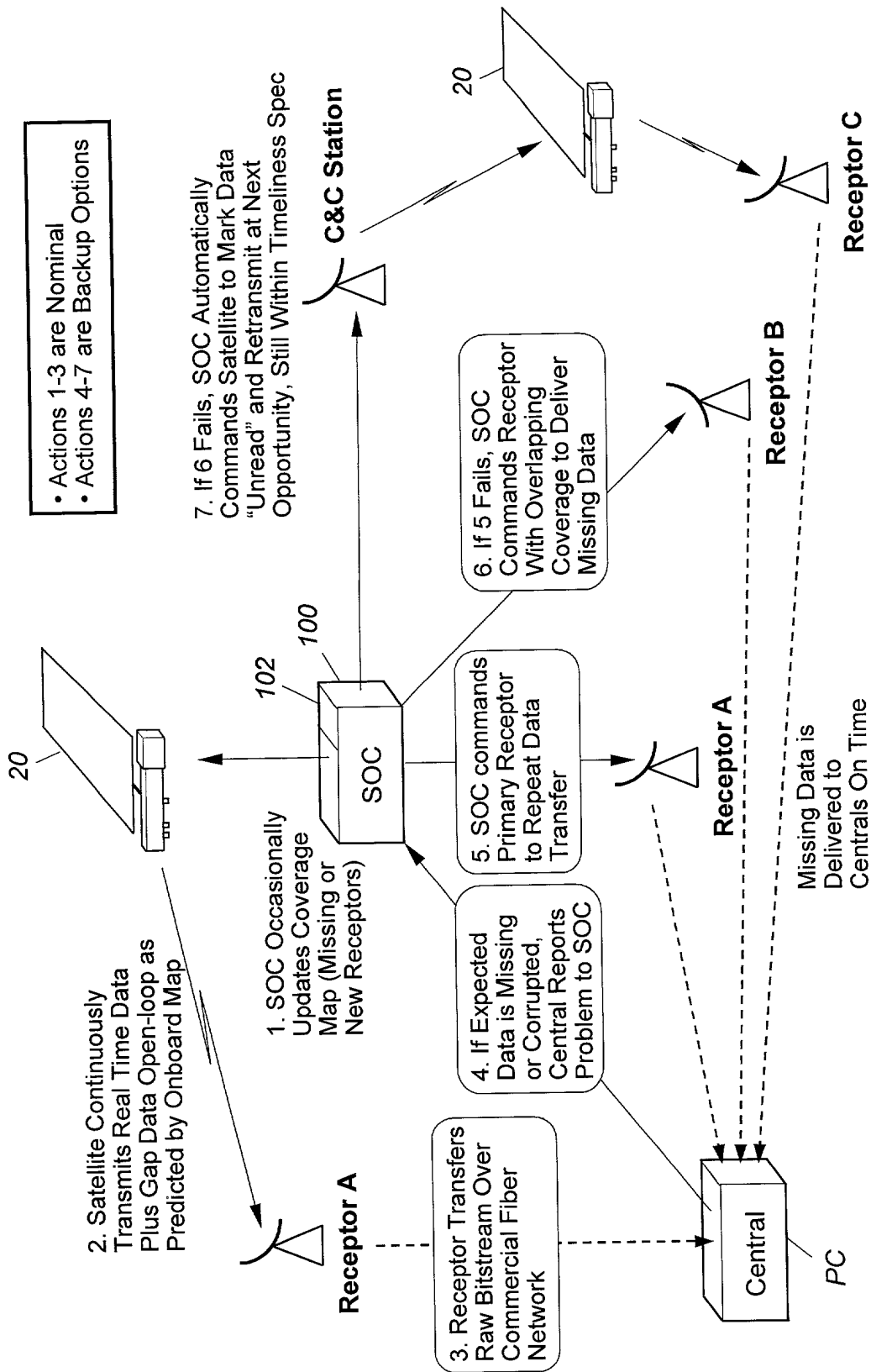


FIG. 4

DECLARATION FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled SATELLITE PAYLOAD DATA COMMUNICATIONS AND PROCESSING TECHNIQUES the specification of which

X is attached hereto

_____ was filed on _____ as Application
Serial No. _____ and was amended on
_____.
(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)

Priority Claimed

NONE
(Number)

(Country)

(Day/Mo./Yr. Filed)

Yes

No

Docket No. 35-0017

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

<u>NONE</u> (Number)	<u> </u> (Country)	<u> </u> (Day/Mo./Yr. Filed)	<u> </u> (Status)
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I hereby appoint as principal attorneys:

Robert W. Keller, Reg. No. 25,347
Michael S. Yatsko, Reg. No. 28,135
Connie M. Thousand, Reg. No. 43,191
William M. Wesley, Reg. No. 26,521

each with full power to prosecute this application, to transact all business in the United States Patent and Trademark Office connected therewith, and to appoint and revoke associate and substitute associate attorneys.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Docket No. 35-0017

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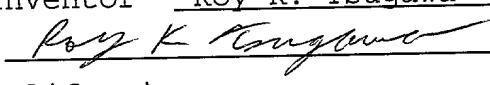
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